

ELECTRONIC FUNDAMENTALS

THEORY LESSON 38

INTRODUCTION TO TELEVISION

- 38-1. Television Camera**
- 38-2. From the Camera to the Screen
of the Receiver**
- 38-3. The Kinescope**
- 38-4. How the Picture on the Kinescope
is Seen**



RCA INSTITUTES, INC.
A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL
350 West 4th Street, New York 14, N. Y.

Theory Lesson 38

INTRODUCTION

Now that you have mastered the material on radio in this course, you are ready to begin your study of television. Television involves the transmission of audible information by means of FM (which you have already studied) and the transmission of visible information by means of AM. In this lesson, you will learn something about the signal that carries visible information and how it is created, transmitted, and received.

If you look at the block diagram of a television system shown in Fig. 38-1, you will see that most of the blocks are labeled with names familiar to you from your study of radio. The blocks that are most unfamiliar are the sync sections in the transmitter and the receiver, the camera tube in the transmitter, and the picture tube in the receiver. Let us examine these stages.

38-1 TELEVISION CAMERA

The purpose of the television camera is to pick up visible information and convert it

to electrical impulses that can be used to amplitude-modulate a carrier wave. A television camera is shown in Fig. 38-2a.

Figure 38-2b shows a simplified drawing of a television camera picking up a scene. The light from the scene is focused by the lens, just as in a photographic camera. The light strikes the screen of the camera tube. As a result, there is a picture of the scene on the screen of the tube.

Breaking up the Image. In order to convert the image on the screen into electrical impulses that can be used to modulate a carrier, the image must be broken up. Before we consider how this is actually done in a television camera let us study the general problem of breaking up an image and how it might be done.

Suppose that you are talking over the telephone to someone to whom you want to describe a photograph so that he can reproduce it. You want the person on the other end of the line to draw a picture that has, as much as possible, the same shape and shades of gray as the one you have in front of you.

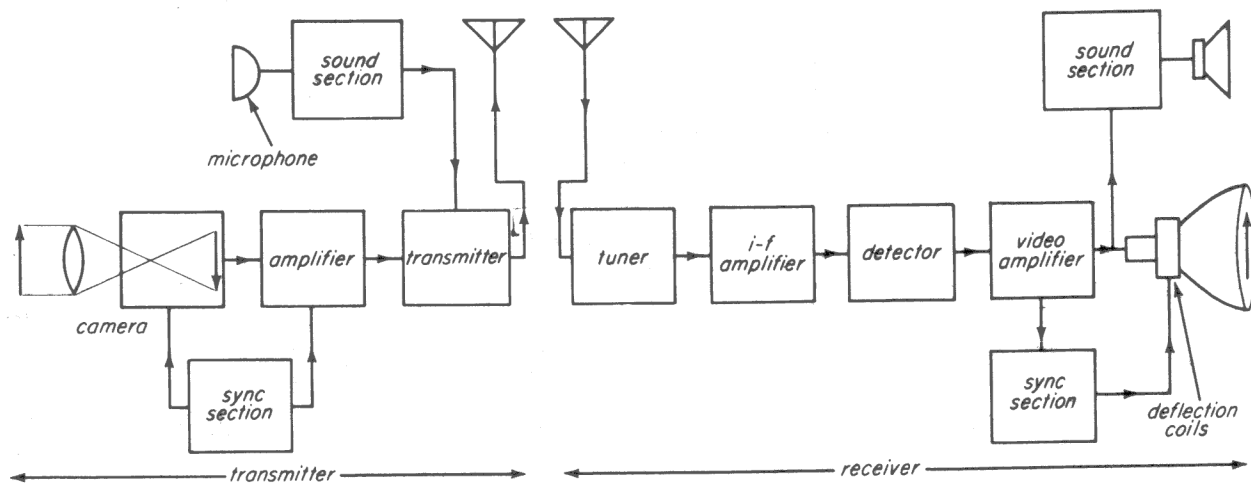
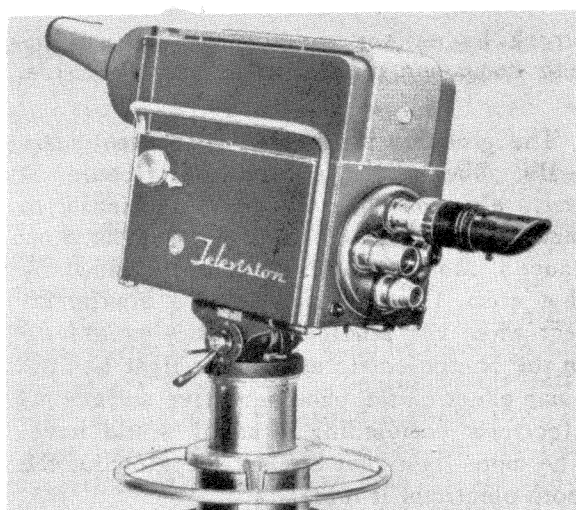
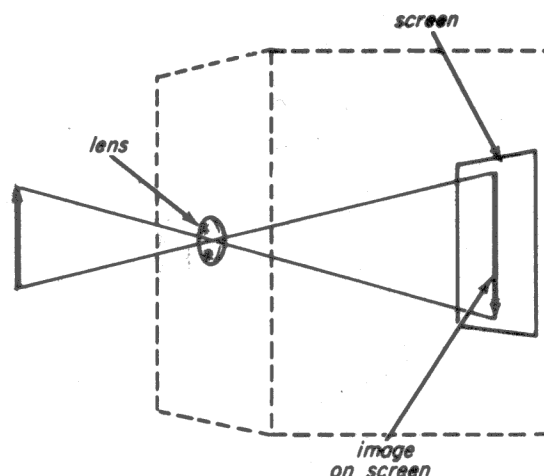


Fig. 38-1



(a)



(b)

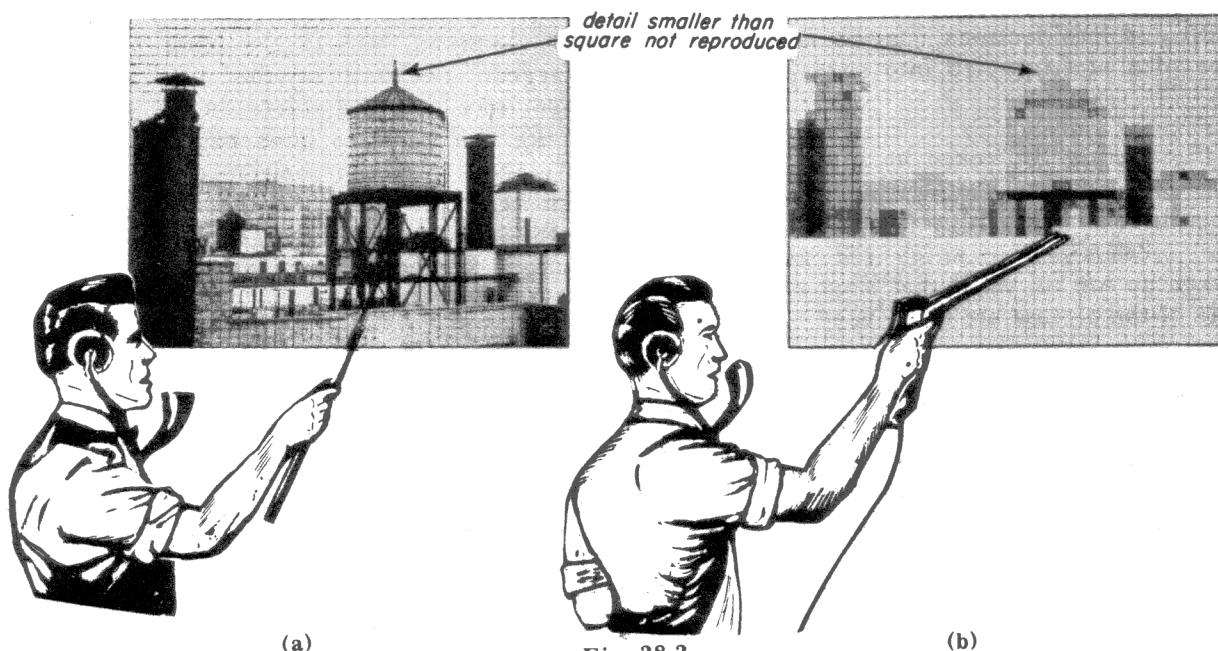
Fig. 38-2

You might do this in the way that is shown in Fig. 38-3. The man shown in *a* has divided his picture into small squares. He has told the man at *b* to obtain a piece of paper of exactly the same size and divide it into squares of the same size. He has also told the man at *b* that the picture he is going to reproduce is in shades of black, gray, and white. The men agree upon some system of identifying the shades. The man at *b* is equipped with a spray gun with which he can apply paint to his paper.

shade he is to place in the corresponding square on his paper. He does this for each square in the first line of squares on the picture. Then he begins at the left-hand side of the second line and does the same thing. He continues, line by line, from left to right and from top to bottom, until he has identified each square and told the man at *b* what shade of gray to put in it. At the end of the conversation, the man at *b* has a picture that resembles the picture shown in *a* of the figure.

The man at *a* decides to begin at the square in the upper left-hand corner of the picture, analyzes which shade of gray is in that square, and tells the man at *b* what

The two pictures are not exactly alike because the man at *b* has been filling entire squares with shades of gray. Some of the



(a)

Fig. 38-3

(b)

details of the picture in *a* take up less than a square. The arrows in the figure indicate such a detail. This means that the square must be filled with more than one shade. If each of the squares of this type could be divided into much smaller squares to the

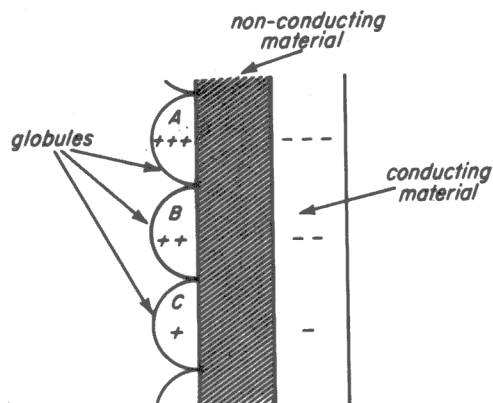


Fig. 38-4

point where filling each of the smaller squares with solid color would produce an exact copy of the picture at *a*, the copy would be more accurate. However, in a picture of this type, such squares would have to be smaller than the eye could see easily.

The screen of the camera tube is broken up into a large number of very small segments. When the light from the scene strikes the screen, some of the light falls on each of the segments of the screen. As a result, the picture is divided into sections, just as it is in the case of a picture ruled into small squares.

The picture is broken up into such tiny sections so that the brightness of each element can be analyzed by the camera. The elements into which the picture is broken up are so small that most of the details of the picture are reproduced.

A cross section of the screen is shown in Fig. 38-4. Notice that the side of the screen on which the picture falls is made up of a large number of globules of silver, upon which have been evaporated a thin layer of a metallic compound that is *photo-sensitive* (capable of emitting electrons when

struck by radiant energy). One photosensitive compound often used is cesium oxide.

The globules are similar to photoelectric cells. When light strikes the globule, it emits electrons. This process is similar to that in which an electron striking an atom causes another electron to be released by that atom. (You learned about a similar effect when you studied secondary emission.) In the photoelectric effect, the light has the same effect on the photosensitive surface as electrons bombarding a metal would have. The more light that strikes the globule, the more electrons it releases.

As you can see in the illustration, the globules are mounted on a nonconducting material, and are separated from each other. On the other side of the nonconducting material is a solid piece of conducting material. Thus, the screen is actually made up of many tiny capacitors. Each globule is one plate of a capacitor, and the area on the solid conducting material opposite the globule is another plate. The nonconducting material in between is the dielectric.

In the figure, globule *A* has been struck by the most light. Therefore, it has lost the most electrons, and, as a result, is the most positive. Globule *B* has been struck by less light, has lost fewer electrons, and is therefore less positive. Globule *C* has been struck by the least light, has lost the fewest electrons, and is the least positively charged. Because of the way in which capacitors act, the points on the plate opposite the globules have negative charges in proportion to the positive charges on the globules. The points on the opposite plate keep their separate charges because these charges are bound in place by the charges on the globules opposite them.

Let us return to the screen as a whole. The screen is made up of many lines, and each line has many globules. Each of the globules has a charge that is positive in proportion to the amount of light that has struck it. As a result, the actual scene has been turned into a group of charges that are positive in proportion to the brightness of

each part of the scene. Now it is necessary to pick up this electrical information and convert it into a form in which it can be transmitted.

Scanning. During our discussion of the two men and their telephones, we mentioned that the man describing the picture starts at the upper left-hand corner and describes the topmost row of squares. When he comes to the end of the first row, he begins at the left-hand square of the second highest row. In other words, he goes across the picture systematically. The man who is listening to the description can follow it easily if he is aware of the systematic pattern that the man who is describing the picture is using.

The picture in charges on the screen of the camera tube is gone over electrically in

a similar way. This process is called *scanning*.

In Fig. 38-5, you can see how this scanning is done. The beam from the electron gun, controlled by the deflection coils, is sent across the screen, one line at a time, from left to right and from top to bottom, just as in the case of the men conveying picture information over the telephone. The collector ring is used to pick up the electrons that the light has forced off the globules. These electrons are of no use.

As the beam strikes a positively-charged globule, the electrons from the beam replace the electrons that the globule had lost when it became positively charged. As a result, the other plate of the capacitor of which that globule is a part discharges. Connected

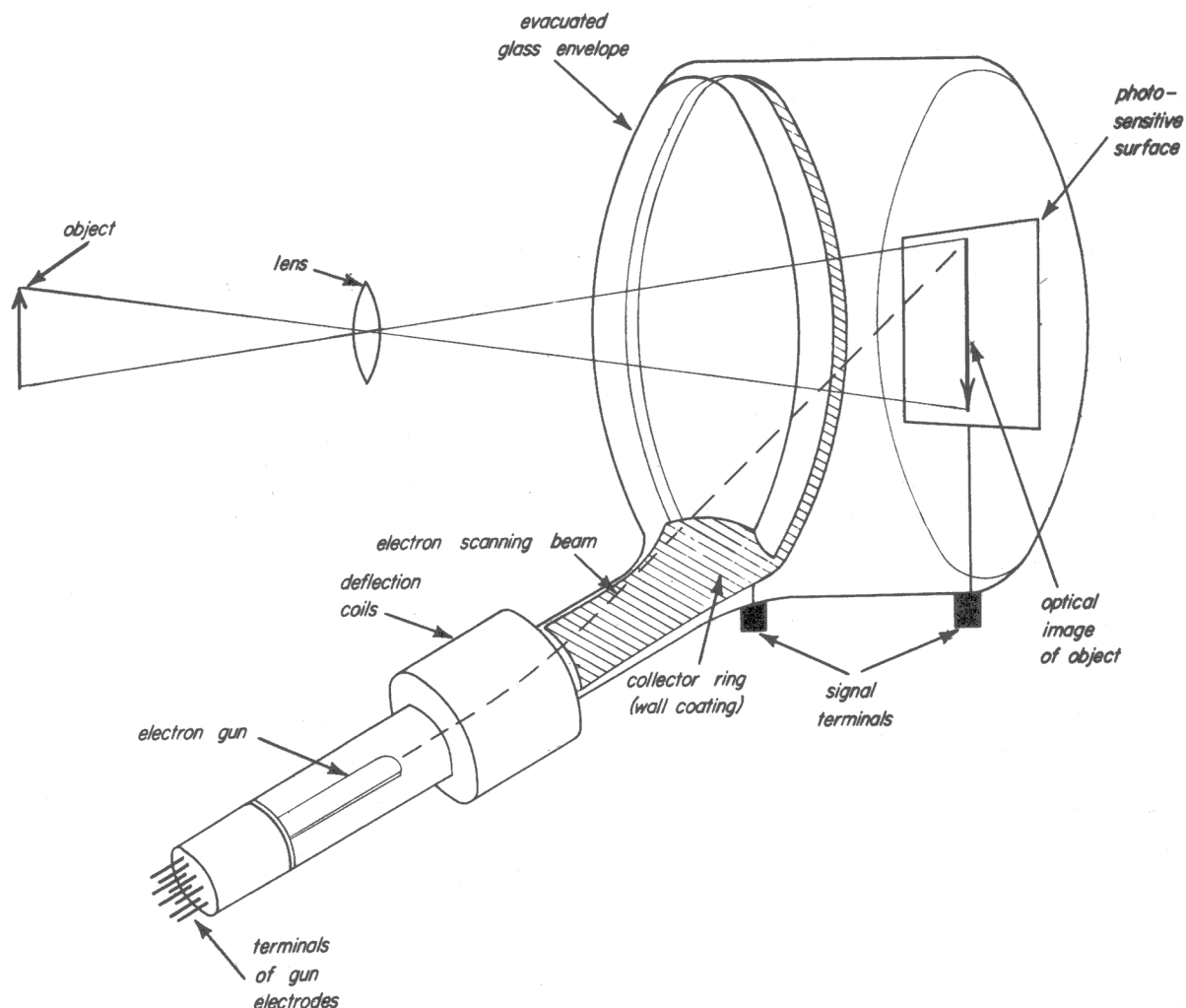


Fig. 38-5

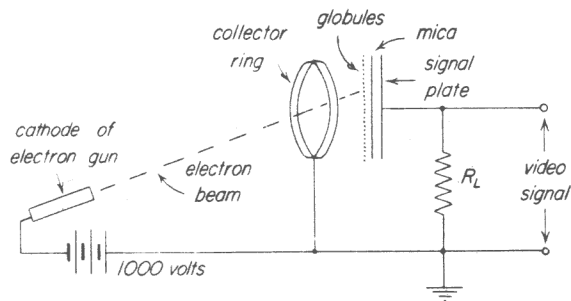


Fig. 38-6

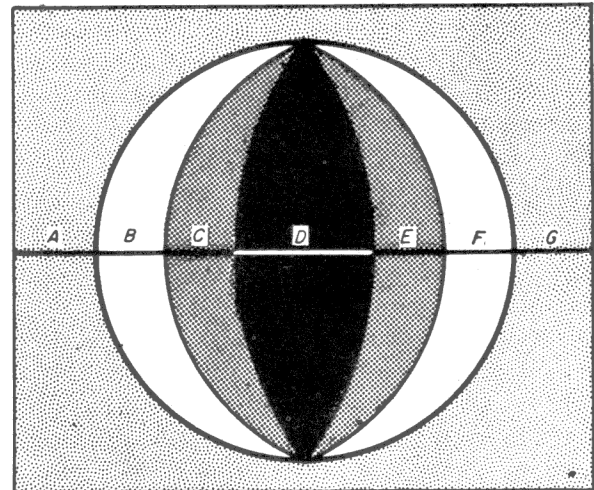
to the plate opposite the globules is a load resistor (Fig. 38-6). As the electron beam strikes a globule, the capacitor formed by that globule and the part of the plate opposite it discharges through the load resistor. The voltage across the load resistor is the signal voltage. The voltage varies with the charges on the globules.

The discussion of the camera tube that you have just read is considerably simplified. A more complete discussion would include many details. For the sake of explaining the basic principles as clearly as possible, those details have been omitted.

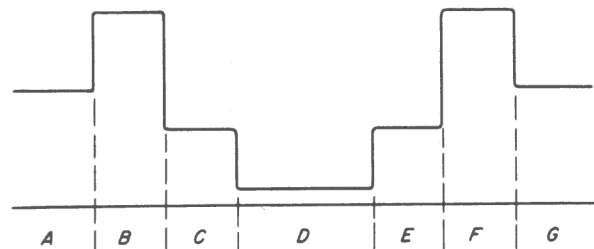
Video-Frequency. The voltage across the load resistor is a pulsating direct current; it changes in frequency, even though it does not change in direction. If a charge at one point on the screen is greater, the voltage across the load resistor has a greater amplitude. The lighter the area being scanned, the greater is the charge. As the beam scans two adjacent charged areas on the screen, the change in amplitude constitutes a single cycle.

Examine the picture in Fig. 38-7a. A single line of the screen is shown outlined. Different parts of the line have different shades of gray. The waveform in *b* shows the relative amplitudes of the voltage across the load resistor as the beam scans the screen across this line. This signal is called the video signal.

In the course of one second, during which the beam scans the screen many times, the frequency across the load resistor changes. The frequency is higher when the beam



(a)



(b)

Fig. 38-7

scans small details, and lower when the beam scans large details, as shown in Fig. 38-7b.

Inasmuch as there are many frequencies across the load resistor during one second, we cannot speak of a constant frequency across the load resistor in cycles per second. All we can do is speak of the frequency at any instant. However, we still express this instantaneous frequency in cycles per second. As shown in Fig. 38-8, there may be many frequencies during the fraction of a second required to scan a single line.

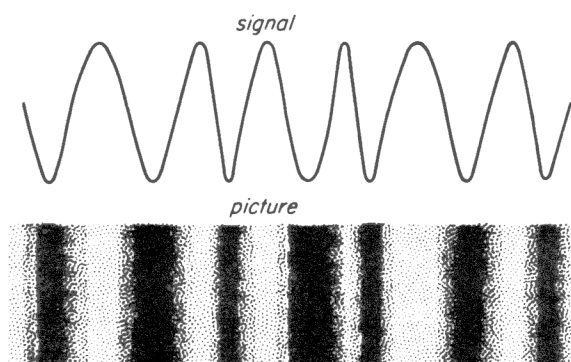


Fig. 38-8

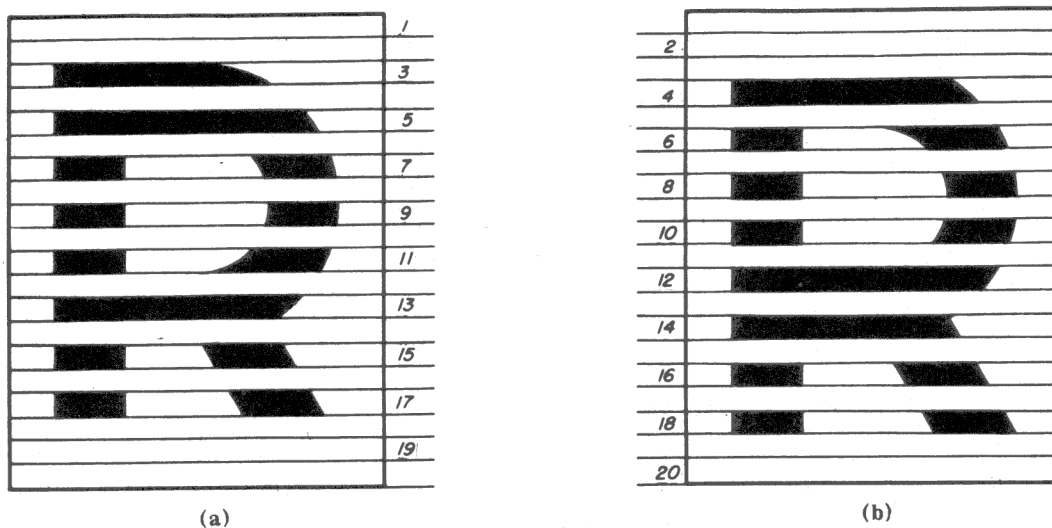


Fig. 38-9

When adjacent areas of different grayness are small, the frequency is higher than when adjacent areas of different grayness are large. The shorter the duration (width) of the pulse, the higher is the frequency necessary to transmit it. The range of frequencies required to transmit information for the television picture is from about 30 cycles to 4 mc.

Interlaced Scanning. The picture on the television is scanned by means of a system called interlacing scanning. This method is illustrated in Fig. 38-9, in which the letter R is being scanned.

The electron beam starts at the upper left-hand corner of the screen, scans across the first line, skips the second line, starts at the left-hand side of the third line, scans it, and then continues in this pattern until all the odd-numbered lines are scanned, as shown in Fig. 38-9a. Then the beam starts at the left-hand side of the second line and scans all the even numbered lines, as shown in Fig. 38-9b. Each time that the beam has scanned either a complete set of odd numbered lines or a complete set of even numbered lines, it has scanned a *field*. In television cameras, 60 fields per second are scanned. Two fields together make up the complete picture, called a frame, as you can see if you imagine Fig. 38-9b superimposed upon Fig. 38-9a. The picture is scanned 525 times each frame, at a rate of 15,750 times per second. Each field contains $262\frac{1}{2}$ lines.

The way that the beam gets from one line to the other is shown in Fig. 38-10. Notice that the electron beam does not go straight across the screen. Instead, it moves across the screen along a line that slopes down to the right. If you remember what you learned about vectors, you can see that the motion of the beam has a horizontal component and a vertical component.

When the beam gets to the end of a line that it is scanning, it moves back to the left of the screen along a line that has both horizontal and vertical components. During that time that the beam is moving across the screen from the end of the line it has just finished scanning to the beginning of the next line that is going to scan, the beam is cut off by means of *blanking* voltage from the sync section. When the beam is cut off, it does not cause a video voltage across the

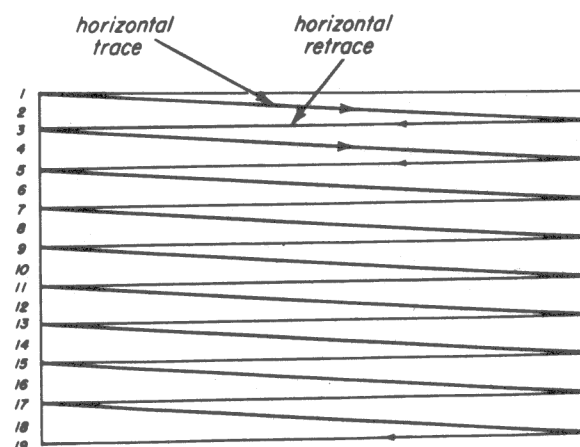


Fig. 38-10

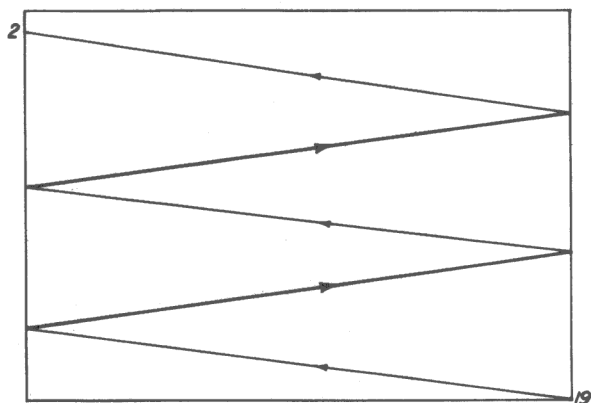


Fig. 38-11

load resistor. The period during which the beam finishes scanning one line and begins to scan the next line is called the *horizontal retrace time*.

After the beam reaches the end of the last line that it scans during a field, it is caused to go back to the top of the screen to the point where it is going to begin to scan the next field. The beam travels along a path like the one shown in Fig. 38-11. The period during which the beam is going from the end of the last line it has scanned in one field to the point at which it is going to begin to scan the next field is called the *vertical retrace time*. In the figure, the vertical retrace is shown going up from the last odd numbered line to the first even numbered line. The beam is cut off during vertical retrace.

As a result of interlaced scanning, the effect of two pictures for each frame is produced. Thus, the time interval between pictures is reduced, and, as a result, picture flicker is reduced.

Moving and Timing the Beam. The beam is caused to scan the screen by means of magnetic deflection. Since the beam must be deflected both vertically and horizontally, two pairs of deflection coils are used.

You are already familiar with electrostatic beam deflection from your study of the oscilloscope. Let us consider how the beam is deflected magnetically in a television camera.

Figure 38-12 shows two pairs of coils mounted on the outside of the neck of the television camera tube. One pair of coils,

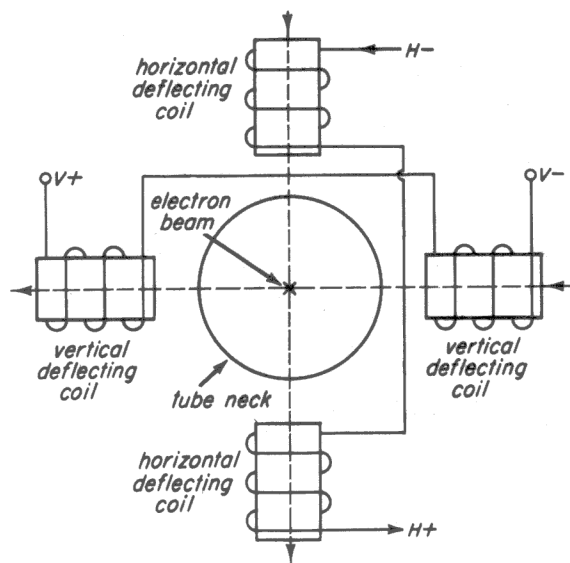


Fig. 38-12

the horizontal deflecting coils, is placed above and below the axis of the beam and connected in series. The other pair of coils, the vertical deflecting coils, are also connected in series and mounted to the right and the left of the beam axis.

The electron beam that is used to scan the screen is an electric current that does not flow in a wire. The electron beam can be deflected by the fields of the coils at a right angle to the direction of its motion and at a right angle to the direction of the field.

A magnetic field exerts a force upon a current passing through it. In Fig. 38-12, the direction of the field of force between the vertical deflecting coils is horizontal. As a result, by applying the left-hand rule, you can see that the beam will be deflected up and down.

The direction of the magnetic field between the horizontal deflecting coils is from top to bottom. Applying the left-hand rule once more, you can see that the beam is deflected horizontally.

You remember from your study of oscilloscopes that it is necessary to produce a sawtooth voltage for application to the deflection plates in order to cause linear electrostatic deflection. In the television camera, it is necessary to produce a sawtooth *current* in each pair of deflection coils.

Fig. 38-13a shows the waveform of current through the horizontal deflection coils, and its action on the electron beam. When the current is zero, the beam is not deflected. As the current rises in the positive direction, the magnetic field between the coils rises in direct proportion to it, and the beam is deflected to the right. When the beam reaches the right-hand side of the line that it is scanning, a sync pulse, which is sent from the sync section to the circuit producing a sawtooth, causes the current to drop to zero and reverse, as shown. The magnetic field quickly falls to zero and then increases in the opposite direction. This causes the electron beam to be rapidly deflected from the right hand side to the center of the screen and past the center of the screen over to the left hand side. This is called *retrace*. As will be described later, this retrace is blanked out; that is, it is made invisible so as not to interfere with the picture.

Look at the waveform for the vertical deflection coil shown in Fig. 38-13b. The sawtooth current is supplied to the vertical deflection coil at the same time as the saw-

tooth current is supplied to the horizontal deflection coils. When the vertical sawtooth is at zero, the beam is at the top of the screen. All during the time that the current in the horizontal deflection coil varying as shown in the waveform of Fig. 38-13a for each of the lines of a single field, the current in the vertical deflection coil is going from zero to maximum once. Therefore, during a field, the vertical deflection coils exert a downward pull on the beam as it goes back and forth across the screen. Finally, at the end of the field, when the beam has scanned the bottommost line of the field, a sync pulse from the sync section causes the current supplied to the vertical deflection coils to fall to its starting point. As a result there is no longer a downward pull on the beam; the beam moves to the top of the screen. This movement of the beam is called *vertical retrace*. When the vertical-deflection current has dropped to its starting level, the beam has completed vertical retrace and is at the top of the screen again, ready to begin to move downward once more.

During both horizontal and vertical retrace, the *blanking pulse* from the sync section lowers the intensity of the beam to a point at which it does not produce video voltage. The pulses that control the timing of the vertical and horizontal scanning are supplied by the sync section, which is shown in the simplified block diagram in Fig. 38-1. You have already learned something about how a sync section operates from your study of the oscilloscope.

Composite Signal. The signal that is broadcast by the transmitter to the receiver contains all the necessary information that the receiver needs to reproduce the picture. All of this information is combined into a *composite* signal that is used to modulate the carrier wave. This composite signal consists of the components described below.

1. The video signal is obtained across the load resistor R_L shown in Fig. 39-6. This signal contains the information as to the lightness and darkness of each element or tiny part of the picture.

2. Near the end of each line, the horizontal blanking pulse is inserted into the com-

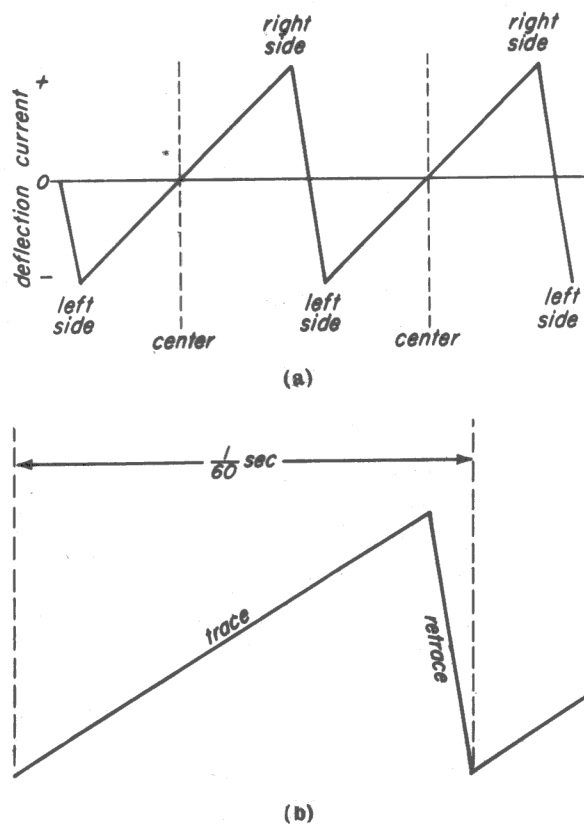
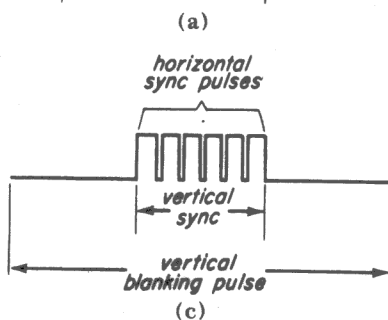
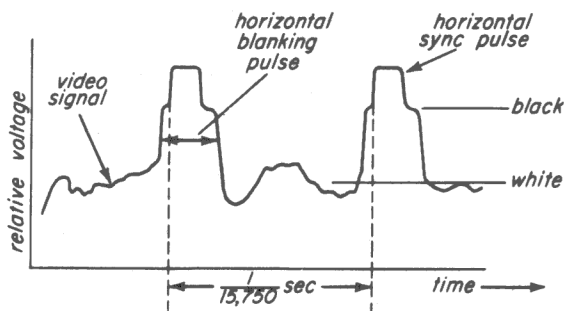


Fig. 38-13

posite signal followed by the horizontal sync pulse. The blanking pulse turns off the picture a little before the end of each scanning line, and keeps it blanked out until a little after the start of the next scanning line. This allows the horizontal retrace to take place without being visible. During the blanking period, the horizontal sync pulse causes the scanning line to start retrace. Figure 38-14a shows the video signal and the horizontal blanking and sync pulses for several horizontal lines. Note that the signal is arranged so that the dark parts of the picture are represented by the highest voltage, and the light parts of the picture are represented by the lowest voltages. This is called negative picture transmission, and is standard in the United States.

3. At the bottom of the picture, the vertical blanking pulse is inserted into the com-



posite signal so as to turn off the picture in order to make the vertical retrace invisible. The vertical sync and blanking pulse is shown added to the composite signal in Fig. 38-14b.

4. The vertical pulse is quite long compared to the time duration of a horizontal line, as shown in the figure. If no horizontal sync pulses were sent during the long vertical pulse, the horizontal oscillator would get out of step. It would be difficult to get it back in step quickly after the end of vertical blanking. Therefore, horizontal sync pulses are continued during the vertical pulse. They are transmitted as serrations of the vertical pulses, as shown in Fig. 38-14c.

5. Because of interlaced scanning, one vertical field is displaced slightly from the next. To prevent this from causing a scanning error, equalizing pulses are transmitted before and after the vertical sync pulse, as

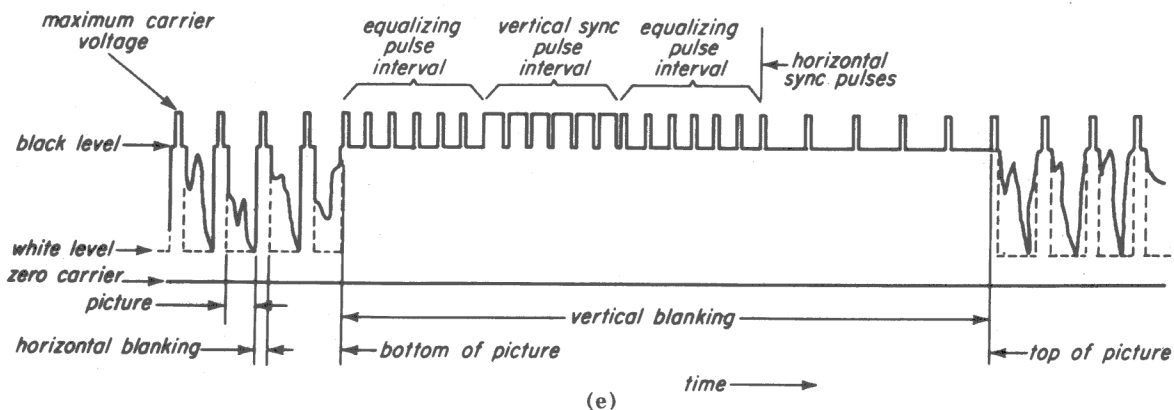
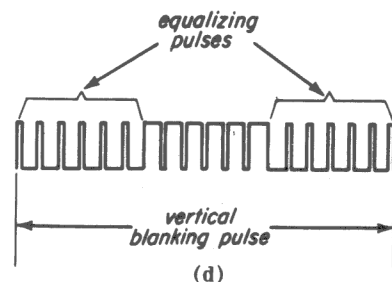
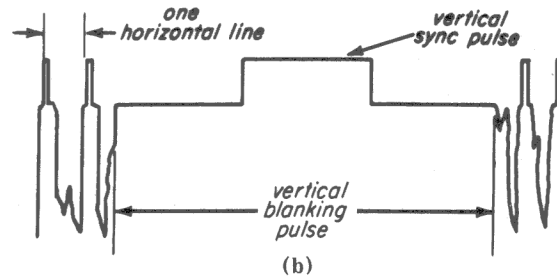


Fig. 38-14

shown in Fig. 38-14d. When the complete vertical pulses are combined with the horizontal pulses and video information, the complete composite video signal appears as shown in Fig. 38-14e.

For each field, that is scanned, there are $262\frac{1}{2}$ lines; about 7 percent of these are invisible due to vertical blanking.

After the video information and the horizontal blanking and sync pulses have been sent out $262\frac{1}{2}$ times, the vertical sync pulse is sent out once. In the drawing of the composite signal, the few sections that show video information and horizontal blanking and sync are intended to represent the $262\frac{1}{2}$ sections that should be shown for every vertical pulse.

Following the vertical pulse shown on the figure is another section of the waveform that shows video information and horizontal blanking and sync. This represents the beginning of a new field. The new field begins, as you have learned, after the vertical retrace at the end of the field before it has been completed.

When the composite signal is picked up by the receiver, the portion of the signal that has the lowest amplitude produces the lightest shade on the screen of the receiver's picture tube. The part of the signal with the highest amplitude produces the blackest shade.

38-2. FROM THE CAMERA TO THE SCREEN OF THE RECEIVER

If you look at the block diagram in Fig. 38-1, you will notice that after the composite video signal leaves the camera, it travels through stages in the transmitter that are similar to those you have already learned about during your study of radio. However, unlike radio, the television system has two blocks called sync sections, one in the receiver and one in the transmitter.

Sync Sections. You have already learned that the output of the sync section in the transmitter is fed to the television camera in order to control the timing of the electron beam that scans the screen. The sync output

is also fed into the amplifier, from which it travels, with the other components of the composite video signal, to the receiver. In the receiver, the sync signal is fed from the video amplifier to the sync section of the receiver. The output of this sync section is used to control the current in the deflection coils of the picture tube, which controls the timing of the scanning on the screen of the picture tube.

As a result of sending the sync signal from the transmitter to the receiver, the receiver picture tube is synchronized with the television camera. The 60 fields per second that are scanned by the camera are in step with the 60 fields per second that appear on the screen of the receiver.

Signal Transmission. The picture information signal is carried by an amplitude-modulated wave. The wave is modulated by the composite video signal, which includes all the information necessary to reproduce and synchronize the picture at the receiver. One sideband is suppressed by means of a filter circuit. The sound is transmitted on a frequency-modulated carrier wave, with which you are familiar from your study of radio. Both the sound signal and the video signal are transmitted from a single antenna and received by a single antenna.

Television signals are transmitted in the frequency band from 54 to 72 mc, and from 76 to 88 mc. In these two bands, there are five *channels*, as the parts of the spectrum allotted to each broadcasting station are called. In the band from 174 to 216 mc, there are seven channels. Each station is allotted 6 mc by the Federal Communications Commission. The break in the band from 88 to 174 mc, is occupied by other communications services. Television is also transmitted on the band between 470 to 890 mc; there are 70 channels in this band.

The frequencies at which television signals are transmitted are in the very-high-frequency range. Such high frequencies are not, as a rule, reflected from the ionized layer of gases that reflects radio waves. Instead, television signals travel in a ground wave. Therefore, the distance over which television signals may be sent is determined by the limitations of line-of sight transmission.

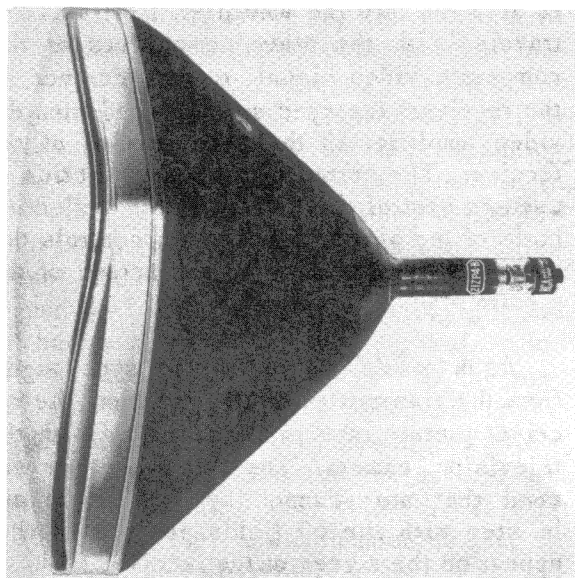


Fig. 38-15

38-3. THE KINESCOPE

By examining the block diagram in Fig. 38-1, you can see how the signal is received, amplified, and detected. From your knowledge of radio, you are already familiar with most of the functions of the blocks in the diagram. As a matter of fact, you are already somewhat familiar with the principles of the operation of picture tube, or *kinescope* (shown in Fig. 38-15), from your study of the oscilloscope. Figure 38-16 shows a simplified cross-section of a kinescope.

Like the oscilloscope tube, the kinescope has an electron gun that emits a beam of electrons from the cathode. This stream of electrons is attracted to the screen as the result of high positive potentials on the accelerating grid and the second anode.

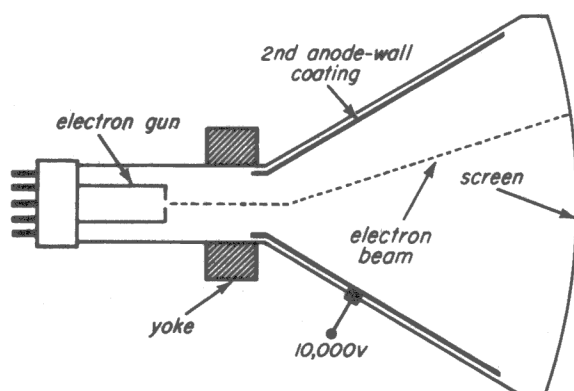


Fig. 38-16

The screen is coated with a phosphorescent material that glows brighter in proportion to the strength of the beam from the electron gun.

The strength of the beam is varied by means of the control grid. The picture information from the video signal is impressed upon this grid to vary the grid voltage and, consequently, the number of electrons in the beam that strikes the screen.

Horizontal and vertical deflection voltages are fed to the horizontal and vertical deflection coils, which are inside the yoke (the cylinder-shaped container around the neck of the tube). As a result, the beam is caused to scan the screen from right to left and from top to bottom. Just as in the case of the camera, the beam scans every other line, first the odd lines and then the even lines. The beams scan at the rate of 60 fields per second. This rate is controlled by the sync pulses.

Blanking pulses transmitted as part of the composite video signal cause the beam to blank out during horizontal and vertical retrace.

38-4. HOW THE PICTURE ON THE KINESCOPE IS SEEN

From the description of the picture on the kinescope, you have learned that it is made up of many separate dots of different shades of gray. You have also learned that first every other line of the scene appears on the screen and then the lines are filled in. Furthermore, the picture on the screen is a moving picture. The reasons that you see what you do on a television screen depend upon certain characteristics of the way in which we see things.

Resolution. Let us consider how it is possible to see a picture that seems to be unbroken when that picture is actually made up of individual dots.

Look at a photograph in a newspaper. At first glance, you see what appears to be an unbroken picture. Then bring the photograph close to your eyes. You can see that

the picture is actually made up of a large number of dots. When this picture is held away from your eyes, it looks like a continuous picture.

Apparently your eyes tend to blend the dots into one another when the picture is held far enough away from them. Because of this characteristic of human vision, it is possible to have television pictures in the form of dots.

Persistence of Vision. The neon bulb you got with this course goes on and off 120 times per second as the a.c. varies at 60 cps, yet the bulb seems to be lighted constantly.

As a matter of fact, whenever you look away from something, you seem to see it for a brief period after you have looked away from it. As a rule this *after seeing*, called *persistence of vision*, does not last long enough for you to be conscious of it as such.

When you look at a television screen that is being scanned in an interlaced pattern, the light from the first *field* to be scanned stays in your consciousness while the second *field* is being scanned. As a result, you see what appears to be a complete picture.

For the same reason, the entire first frame remains in your consciousness long enough for the second frame to take its place. As a result, you see what appears to be a moving picture.

As a matter of fact, the same principle of persistence of vision is used in movies. Movies consist of a long strip on which are printed a large number of still photographs. Each photograph differs very little from the one that follows it on the strip. When the strip of film is run through a projector at a rapid rate, what actually happens is that a series of still photographs is projected on the screen. One photograph follows the other so rapidly that persistence of vision keeps you conscious of one picture while the picture following it is projected on the screen.

You see what seems to be a picture that

moves. You are not directly conscious of persistence of vision as such, for the effect lasts only for about 1/10 of a second.

Sequential Picture. Although persistence of vision helps you to see separate frames as a continuous moving picture on the television screen, persistence of vision alone is not enough. It is also necessary that there be persistence of the image itself. In order to understand this better, let us reconsider the photograph in a newspaper. This type of photograph, as we have pointed out, is made up of dots. All the dots together make up the picture, and all the dots that make up the picture are there *simultaneously* (at the same time). But in a television picture, all the dots are not there at the same time. As the beam scans, the globules are illuminated one after the other, and the rows of globules are illuminated one after the other as the beam travels from the top to the bottom of the screen. Instead of all the globules being illuminated at once, which would be simultaneous transmission, the globules are illuminated one after the other in a regular pattern or, *sequentially*.

However, when the viewer looks at the screen, portions of the screen that are not being scanned do not lose all their brightness. The globules that are not being scanned at a particular instant lose so little of their brightness during a frame that a person looking at the screen is not aware of the change. This is because the screen is coated with a *phosphorescent* material—a material that emits light both when it is stimulated by an outside source of energy and also for a brief time after the outside energy is no longer stimulating it. Thus, all parts of the picture on the screen seem to be produced simultaneously.

The existing television bandwidths established by the FCC are not wide enough for simultaneous transmission. Furthermore, existing equipment operates excellently by the sequential transmission method. You will learn how the receiver processes the sequential signal in Theory Lesson 39.